

A RESEARCH NOTE

TENDERIZING CALLIPYGE LAMB WITH THE HYDRODYNE PROCESS AND ELECTRICAL STIMULATION¹

M.B. SOLOMON^{2,6}, C.E. CARPENTER³, G.D. SNOWDER⁵ and N.E. COCKETT⁴

²*Meat Science Research Laboratory
USDA, ARS
Beltsville, MD 20705*

³*Dept. of Nutrition and Food Sciences*
⁴*Dept. of Animal and Veterinary Sciences
Utah State University
Logan, UT 84322*

⁵*U.S. Sheep Experiment Station
USDA, ARS
Dubois, ID 83423*

Received for Publication on September 12, 1997
Accepted for Publication on January 5, 1998

ABSTRACT

The effectiveness of the Hydrodyne process and low voltage carcass electrical stimulation (ES), either alone or in combination, for tenderizing muscle from callipyge and normal lambs was evaluated. One hundred grams of explosive was used for the Hydrodyne treatment. Reductions in shear force with magnitudes of 33 to 67% were observed for the Hydrodyne treatment for the longissimus (LM) muscle from callipyge and normal lambs, respectively. Carcass ES had no effect ($P>0.05$) on either callipyge or normal lamb shear values. However, ES improved the response (48%) of the Hydrodyne treatment in the LM of callipyge lamb. Shear force for semitendinosus muscles averaged 3.53 kg and showed no response to either tenderizing treatment. Results suggest successful tenderization of lamb LM with the Hydrodyne technology.

¹The USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of other products that may also be suitable.

⁶To whom correspondence should be addressed.

Journal of Muscle Foods 9 (1998) 305-311. All Rights Reserved.

©Copyright 1998 by Food & Nutrition Press, Inc., Trumbull, Connecticut.

INTRODUCTION

Increasing demand for leaner meats with less fat has resulted in a need for an effective method of tenderizing. Meat from leaner carcasses has been shown to be tough usually as a result of muscle "cold shortening" (Locker 1985). The recently discovered callipyge gene in lambs has been associated with muscle hypertrophy (Koochmaraie *et al.* 1995). Certain muscles, in particular the longissimus (LM), from callipyge lambs has been found to have a tenderness problem compared to control animals (Field *et al.* 1996; Shackelford *et al.* 1997), but not all muscles that exhibit this hypertrophic condition in callipyge lamb possess this tenderness problem (Shackelford *et al.* 1997). The severity of the problem seems to be specific to the LM. Koochmaraie *et al.* (1995) suggested that both reduced rate of protein degradation and a higher capacity for protein synthesis are consequences of the callipyge condition which in turn are associated with lower meat tenderness resulting from reduced rate and extent of postmortem meat proteolysis.

The Hydrodyne process (Solomon *et al.* 1997), which is totally different from any currently described method(s) for meat/carcass tenderization, uses a small amount of high- energy explosive to generate a supersonic-hydrodynamic shock wave in water. The shock wave passes through objects in the water that are an acoustical match with the water (Kolsky 1980). This shock wave occurs in fractions of a millisecond. Results for normal and cold shortened beef muscles (Solomon *et al.* 1997) suggest up to 72% tenderness improvement when using the Hydrodyne process. An experiment was conducted to determine the effectiveness of the Hydrodyne process and low voltage carcass electrical stimulation, either alone or in combination for tenderizing LM and semitendinosus (ST) muscles from callipyge lambs.

MATERIALS AND METHODS

Animal Selection

Animals (wether lambs) for this project originated from the mating of normal Columbia ewes with heterozygous callipyge rams (1/4 Dorset x 3/4 Columbia). From 3 weeks of age until slaughter, the progeny were visually classified (by two experienced evaluators) as callipyge or normal based on muscle conformation in the hindsaddle and loin regions. The wether lambs were scored every 2 weeks according to the degree of muscle hypertrophy with 1 = definitely normal and 4= definitely callipyge. The scores were summed over the judging period and animals exhibiting mean scores between 2 and 3 were eliminated from the study.

Normal (n=16) and callipyge (n=16) wether lambs (51 to 55 kg) were slaughtered at the Utah State University meat laboratory under USDA inspection

guidelines. These lambs were part of the study by Carpenter *et al.* (1997) designed to determine if various postslaughter processing procedures, either employed individually or in combination, would be capable of producing tender callipyge loin chops. Eight normal and eight callipyge intact carcasses were electrically stimulated (ES) immediately after death and decapitation using a stimulator unit consisting of a rectangular wave of 21 V, 60 Hz, 0.25 amp alternating current (Model BV80 Low Voltage Stimulator, Jarvis Products, Middletown, Conn.). Stimulation was applied in six impulses of 20 s durations each, with 5 to 10 s gaps to allow the carcass to relax between impulses. Nonstimulated (NoES) carcasses were placed directly into the cooler. Stimulated carcasses were conditioned at 27C until pH < 6.0 was obtained in the longissimus, which usually was within 1 h of stimulation, and then were placed into the cooler (2-4C). This method of conditioning was selected based on positive results from prior research (Solomon and Lynch 1991). The LM from the racks corresponding to the loins used by Carpenter *et al.* (1997) and the intact ST muscles were selected for this study. All muscle samples (from the 32 animals in this study) were removed from the carcasses at 1-day postmortem and immediately frozen for subsequent shipping to the Meat Science Research Laboratory, USDA, ARS in Beltsville, Maryland. Muscle samples were removed and frozen at 1-day postmortem as a result of this research being part of a larger study and the convenience of a USDA employee obtaining these samples in Utah and transferring them to Maryland. Additionally, the greatest effect on tenderness when using ES is obtained at 1-day postmortem and subsequent aging diminishes the tenderness differences between ES and non-ES.

Hydrodyne Treatment

Based on initial experiments with four different beef muscles (Solomon *et al.* 1997), 100 g of explosive was selected for this study since it proved to be quite effective in beef. In the Hydrodyne process for experimental purposes, the meat was encapsulated twice, first in a polyolefin resin (Cryovac®, Cryovac North America, Division of WR Grace & Co., Duncan, South Carolina) bag followed by encapsulation in a polymer of isoprene (rubber) bag. Both bags were evacuated. Thawed meat samples were treated with the Hydrodyne process with the bone intact for the rack (LM) samples and boneless for the ST samples. Each LM and ST sample was cut into two equal sections (at anterior and posterior designations along the long axis of each muscle) and randomly assigned as either Hydrodyne treatment or control, nontreated sample. The packaged meat samples described above were supported against the floor of plastic containers (208-L capacity and 51-cm diameter), each fitted with a steel plate (2-cm thick) so the ensuing wave could reflect back through the meat to intersect with the incoming wave. The containers were situated below ground level and filled to the top with water. The

charge incorporated (100 g) was a binary explosive composed of a liquid (nitromethane) and a solid (ammonium nitrate). The explosive was submerged in the water to a distance of 30.5 cm away from the front surface of the meat and wired to a detonating device. The detonating device triggered the detonation of the explosive.

Control and Hydrodyne samples were held and transported on ice to the testing site, and the duration of time that elapsed from the time of treating the samples with the Hydrodyne to the time the samples were cooked was less than 2-3 h. All chops were broiled to an internal temperature of 68C (AMSA 1995) using Farberware Open-Hearth broilers (Model 350A, Walter Kidde and Co., Bronx, N.Y.). Internal temperature was monitored using iron-constantan thermocouples attached to a Speedomax multipoint recording potentiometer (Model 1650, Leeds and Northrup, North Wales, Pa.). After cooking, all chops were allowed to cool to room temperature (25C) before coring. A minimum of two-three cores (1.27 cm diameter) were removed from each chop parallel to the muscle fiber orientation for shear force determination using a Warner-Bratzler shear device mounted on a Food Texture Corp. texture measurement system (Model TMS-90, Chantilly, Va.).

Data were analyzed using analysis of variance and F-tests (SAS 1994) to determine the significance of variation for phenotype, Hydrodyne process, carcass ES and the corresponding interactions. Least squares means and linear contrasts were generated using SAS (1994).

RESULTS AND DISCUSSION

Shear force (Table 1) for nonstimulated (NoES), callipyge control LM was 6.42 kg compared to 5.70 kg for NoES, normal control LM, which were not different ($P>0.05$). The callipyge phenotype has repeatedly been shown to significantly reduce LM tenderness (Koochmaraie *et al.* 1995; Field *et al.* 1996; Shackelford *et al.* 1997). Shackelford *et al.* (1997) reported as much as a 124% increase in LM shear force resulting from the callipyge phenotype (4.5 kg vs 10.1 kg for normal and callipyge lambs, respectively).

LM shear force was reduced 33% (6.42 to 4.26 kg) using the Hydrodyne process in the callipyge NoES lambs, and as much as 67% (5.70 to 1.90 kg) in normal NoES-controls. These effects were in unaged LM and it is likely that the effects observed in the normal LM would most probably be eliminated by typical postmortem aging. In our beef study (Solomon *et al.* 1997), similar 67% reductions were found when LM were treated with 100 g of explosive. Although callipyge LM in this study exhibited a significant response (improvement in tenderness) from the Hydrodyne process, this response was not of the magnitude observed in the normal lambs. Koochmaraie *et al.* (1995) reported that postmortem storage (up to 21 days) had minimal effect on callipyge LM shear force and

TABLE 1.
EFFECT OF PHENOTYPE, HYDRODYNE TREATMENT AND CARCASS ELECTRICAL STIMULATION (ES) ON TENDERIZATION OF LAMB MUSCLES AS MEASURED BY SHEAR FORCE

Shear Force, kg	Phenotype				SEM
	Normal NoES	Normal ES	Callipyge NoES	Callipyge ES	
<u>Longissimus</u>					
Control	5.70 ^a	5.95 ^a	6.42 ^a	6.03 ^a	.56
Hydrodyne	1.90 ^{d*}	2.68 ^{cd*}	4.26 ^{b*}	3.11 ^{**}	.34
<u>Semitendinosus</u>					
Control	3.15	3.58	4.11	3.43	.38
Hydrodyne	2.96	3.43	3.67	3.21	.31

^{a,b,c,d}Within each row means with uncommon superscripts differ ($P < 0.05$).

^{*}Significant Hydrodyne effect ($P < 0.01$).

fragmentation of myofibrils. Both rate and extent of degradation of the muscle proteins associated with postmortem aging were greatly reduced in lambs expressing callipyge phenotype. Furthermore, LM from callipyge (Koochmaraie *et al.* 1995) exhibited a reduced rate of calpain-mediated postmortem proteolysis which was responsible for the reduced rate and extent of postmortem tenderization. Perhaps the factors involved in this inherent difference in callipyge LM was responsible for the inability of the Hydrodyne process to tenderize at the same magnitude as observed for the normal control lambs. This does not discount the possibility that an even greater hydrodynamic shock wave pressure from the Hydrodyne process may be suitable in overcoming the differences and problems in callipyge LM.

Carcass electrical stimulation (ES) had no effect ($P > 0.05$) on either the callipyge or normal lamb LM. However, ES improved the response of the Hydrodyne treatment in the callipyge lambs LM, yet had no effect ($P > 0.05$) in normal lambs LM. Shear values for the Hydrodyne treated normal LM were already low (1.90 kg). Carcass ES may have altered the LM muscle protein integrity of the callipyge lambs allowing it to be more susceptible to the Hydrodyne process. This was the first experiment using the Hydrodyne process on any lamb muscle, much less callipyge lamb, so there was no available literature to make comparisons. In our previous work with beef (Solomon *et al.* 1997), we observed

shear force improvements of the magnitude of 67% in LM when using 100 g of explosives in the Hydrodyne process for muscles whose initial shear values were 7.8-8.3 kg. In that study the muscles under investigation were intentionally 'cold shortened' to assure muscles lacking in tenderness. The results of our study clearly suggest that the Hydrodyne process was effective at instantaneously tenderizing LM from both callipyge and normal lambs and its effectiveness was further enhanced when ES was included as a postmortem treatment.

In a separate study (Zuckerman and Solomon 1997), the ultrastructural changes in bovine LM resulting from the Hydrodyne process (100 g of explosive) was examined. In that study we observed extensive myofibrillar fragmentation in the region adjacent to the Z-lines with fragments of Z-lines attached to the A-band on opposite sides of the fractures. These fractures resulted in increased intramyofibrillar spaces with longitudinal gaps or splits in the myofibril matrix. Perhaps for callipyge LM, 100 g of explosive, which results in estimated wave pressures of ca. 60 to 70 MPa, was not sufficient to cause the extensive fragmentation and protein alterations as seen in our beef study. Alternatively, myofibrillar fragmentation in the Z-line region may not be the major factor in callipyge gene meat toughness. However, when combining carcass ES with the Hydrodyne process, the integrity of the muscle proteins involved in these alterations may have made them more susceptible to the Hydrodyne process. Ultrastructural examination of Hydrodyne treated LM from callipyge ES and non-ES carcasses needs to be investigated.

The ST muscles from the callipyge lambs used in this study (Table 1) did not appear to have the tenderness problem found for the LM. There were no differences ($P>0.05$) in ST shear force between the callipyge (3.75 kg) and normal (3.30 kg) lambs, nor did carcass ES have any effect ($P>0.05$) on shear force. Furthermore, the Hydrodyne process had no effect ($P>0.05$) on ST shear values, which suggests that when tender meat is treated with the Hydrodyne process no additional tenderization is evident and the problem of over-tenderization does not appear to be a concern. Shackelford *et al.* (1997) recently reported on the effects of the callipyge phenotype on tenderness of 7 major muscles of lamb carcasses, which included the LM and ST muscles. They found that the magnitude of the callipyge effect differed among the 7 muscles. ST shear force was 19% greater in callipyge than normal lambs.

CONCLUSIONS

Results indicate that the Hydrodyne process is effective at tenderizing the LM from callipyge, as well as normal lamb, and the tenderization effect is further enhanced in callipyge LM if it is used in conjunction with carcass electrical stimulation. The ST muscle from callipyge lamb does not appear to have the

tenderness problem observed for callipyge LM.

ACKNOWLEDGMENT

The authors greatly acknowledge the technical assistance of Janet Eastridge.

REFERENCES

- AMSA. 1995. Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. Am. Meat Sci. Ass. in cooperation with the National Live Stock and Meat Board, Chicago.
- CARPENTER, C.R., SOLOMON, M.B., SNOWDER, G.D., COCKETT, N.E. and BUSBOOM, J.R. 1998. Effects of electrical stimulation and conditioning, calcium chloride injection, and aging on the acceptability of callipyge and normal lamb. *SID Sheep Res. J.* (In Press).
- FIELD, R.A., McCORMICK, R.J., BROWN, D.R., HINDS, F.C. and SNOWDER, G.D. 1996. Collagen crosslinks in longissimus muscle from lambs expressing the callipyge gene. *J. Anim. Sci.* 74, 2943-2947.
- KOLSKY, H. 1980. *Stress Waves in Solids*. Dover Publishing Co., New York.
- KOOHMARAIE, M., SHACKELFORD, S.D., WHEELER, T.L., LONERGAN, S.M. and DOUMIT, M.E. 1995. A muscle hypertrophy condition in lamb (callipyge): characterization of effects on muscle growth and meat quality traits. *J. Anim. Sci.* 73, 3596-3607.
- LOCKER, R.H. 1985. Cold-induced toughness of meat. In *Advances in Meat Research*, Vol. 1, Electrical Stimulation (A.M. Pearson and T.R. Dutson, eds.) pp. 1-44, Van Nostrand Reinhold/AVI, New York.
- SAS. 1994. *SAS User's Guide: Statistics*. SAS Inst., Cary, N.C.
- SHACKELFORD, S.D., WHEELER, T.L. and KOOHMARAIE, M. 1997. Effect of the callipyge phenotype and cooking method on tenderness of several major lamb muscles. *J. Anim. Sci.* 75, 2100-2105.
- SOLOMON, M.B., LONG, J.B. and EASTRIDGE, J.S. 1997. The Hydrodyne: a new process to improve beef tenderness. *J. Anim. Sci.* 75, 1534-1537.
- SOLOMON, M.B. and LYNCH, G.P. 1991. Combined effects of electrical stimulation, carcass posture and insulated bags on ram lamb tenderness. *J. Muscle Foods* 2, 279-288.
- ZUCKERMAN, H. and SOLOMON, M.B. 1998. Ultrastructural changes in bovine longissimus muscle caused by the Hydrodyne process. *J. Muscle Foods* (In Press).